Capturing Choice Overload via Generalized Markov Chain Model

CENTER FOR FINANCIAL & BUSINESS ANALYTICS
Data Science Institute

Kumar Goutam, Vineet Goyal, Agathe Soret
IEOR Department
Columbia University

Data Science Institute
COLUMBIA UNIVERSITY

Motivation and Introduction

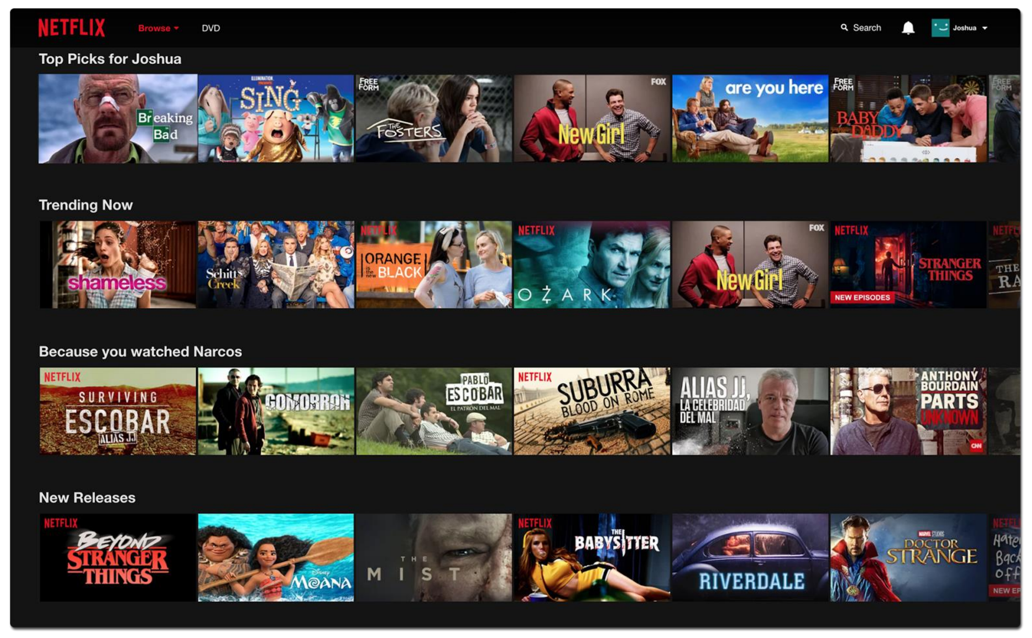


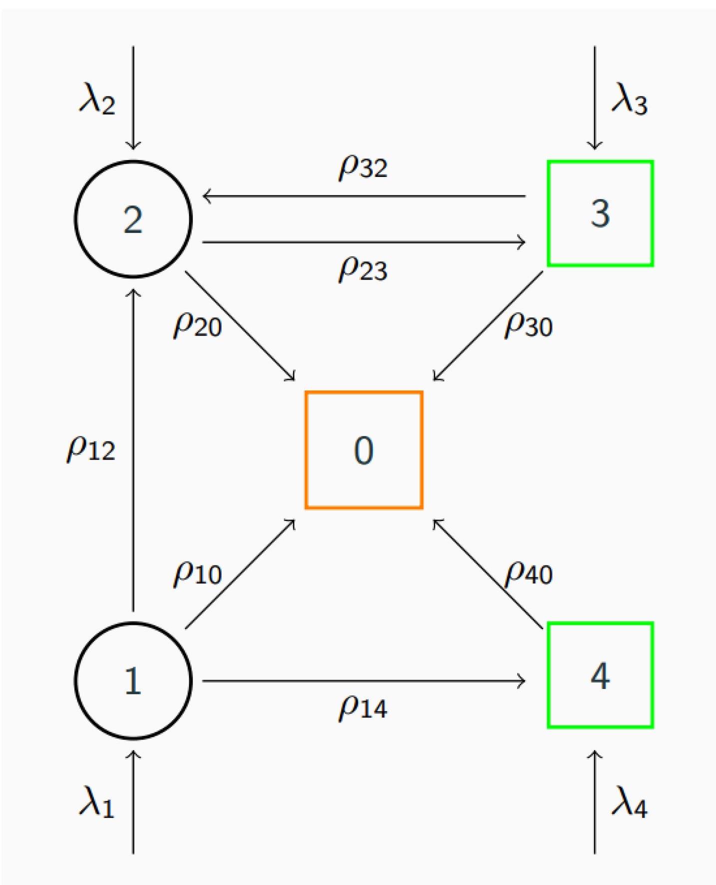
Figure 1. Can't decide what to watch!

- Purchase probability may decrease when the number of offered items increases
- Has been observed empirically: Iyengar and Lepper (2000) [1]
- Called "Choice Overload"

- No Random Utility based choice model can capture choice overload
- For any RUM, probability of no purchase decreases with increasing offer set size

Markov Chain Choice Model

- Each product is a node in the Markov Chain
- Customers do a random walk on this graph
- When they reach an offered product, they simply buy the product



- i Product Node
- 0 No-purchase Option
- λ_i Arrival Probability
- ρ_{ij} Transition Probability
- S Offer Set (Absorbing States)
- $\pi(i,S)$ Probability of buying i when S is offered

Figure 2. 4 products, $S = \{3,4\}$

Theorem: The Markov Chain choice model can approximate any RUM [2]

Hence, it cannot capture choice overload!

Generalized Markov Chain Model

- Key idea: An offered product is not necessarily absorbing anymore!
- For each $i \in S$, if a customer reaches state i, then they
  - either stop at i with a probability $\mu(i,S)$, depending on set of offered products
  - or keep transitioning

$$\mu(i,S) = exp(-\alpha \sum_{j \in S_+} \rho_{ij})$$

Generalized Markov Chain Model

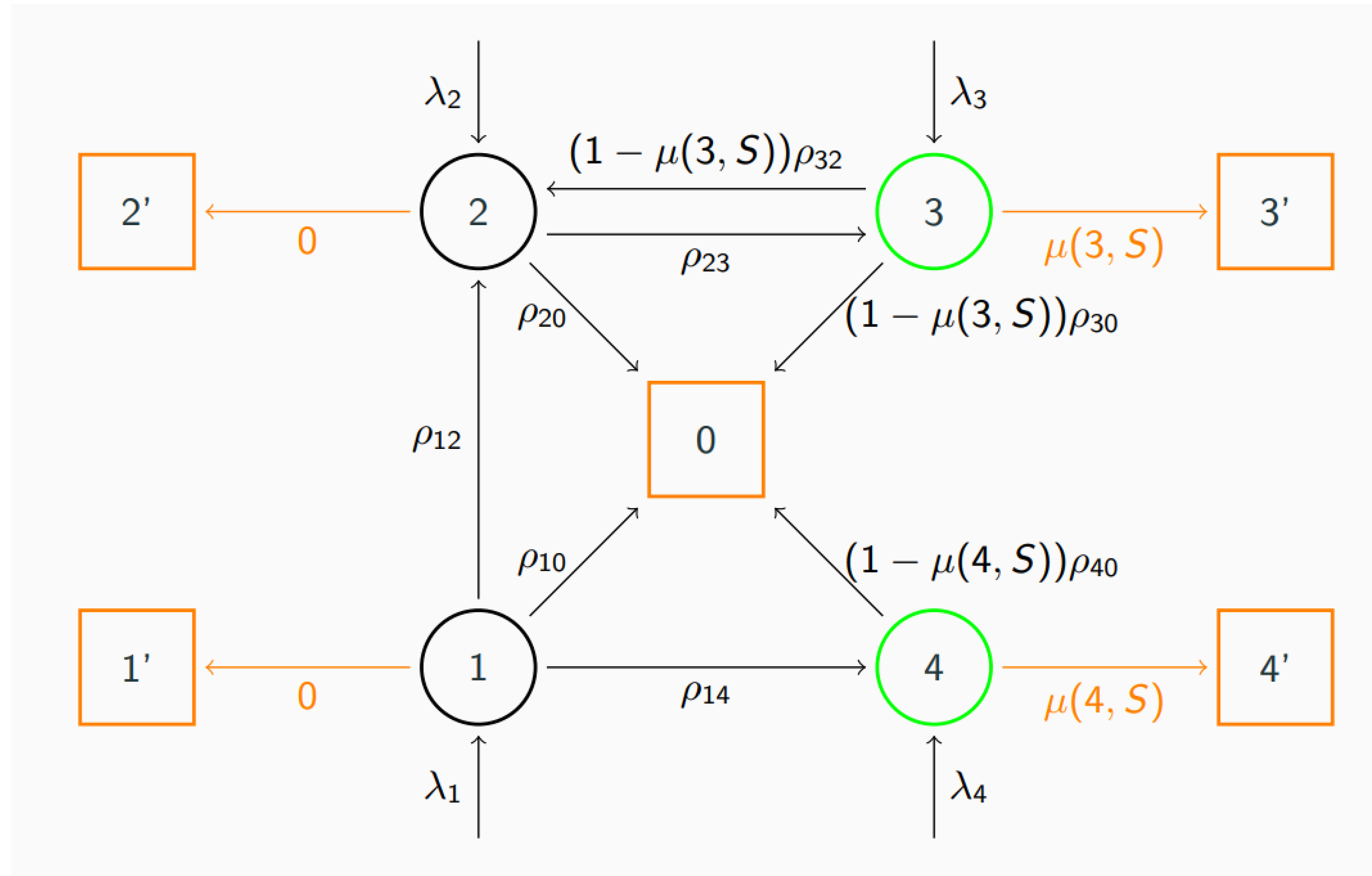
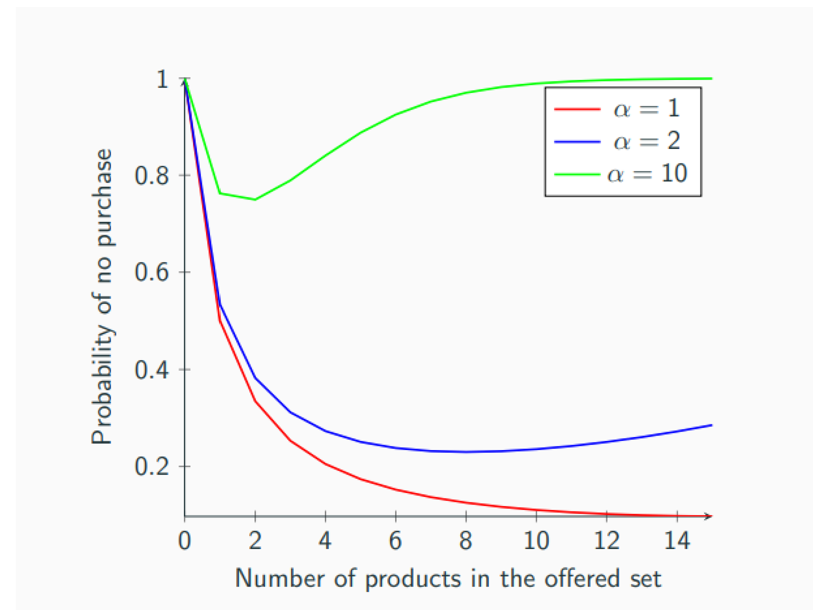


Figure 3. Generalized Markov Chain: modify absorbing states

If more similar products are offered, a customer is less likely to stop and purchase a product

α is a parameter that controls choice overload: a high value of α corresponds to a picky customer



Generalized Multinomial Logit (GMNL) Model

- Transition matrix has rank 1
- $\rho_{ij} = v_j$
- $\lambda_i = v_i$
- $\mu(i,S) = exp(-\alpha \sum_{j \in S_+} v_j)$

Lemma:

$$\pi(i,S) = \frac{v_i}{v_0 e^{\alpha \sum_{j \in S_+} v_j} + \sum_{j \in S} v_j}$$

Assortment Optimization Problem

$$\max_{S \subseteq \mathcal{N}} \sum_{i \in S} \pi(i,S) r_i = \max_{S \subseteq \mathcal{N}} \frac{\sum_{i \in S} v_i r_i}{v_0 e^{\alpha \sum_{j \in S_+} v_j} + \sum_{j \in S} v_j}$$

Theorem 1: The assortment optimization problem under the Generalized Multinomial Logit model is NP-hard.

Hardness ☹

Theorem 2: There is a near-optimal algorithm to the assortment optimization problem under the GMNL model.

FPTAS ☺

- The above two theorems can be extended to low rank case

References

[1] Iyengar, S. S., Lepper, M. R. (2000). When choice is demotivating: Can one desire too much of a good thing? Journal of Personality and Social Psychology, 79(6), 995-1006

[2] Blanchet, J., Gallego, G., Goyal, V. (2016). A Markov chain approximation to choice modeling. Operations Research, 64(4), 886-905